



California State University
MONTEREY BAY
Extraordinary Opportunity

Satellite Mapping of Agricultural Water Requirements in California

Forrest Melton, Sr. Research Scientist
forrest.s.melton@nasa.gov

**L. Johnson, C. Lund, A. Guzman, K. Post, S. Hiatt, C. Rosevelt,
G. Miller, A. Michaelis, P. Votava, R. Nemani**
CSU Monterey Bay / NASA ARC-CREST

Kent Frame, Bekele Temesgen, Morteza Orang, Cayle Little
CA Dept. of Water Resources

Partners:

CA Dept. of Water Resources, Western Growers Association, Center for Irrigation Technology / CSU Fresno, USDA ARS / NRCS, Univ. of California Cooperative Extension, USGS, Booth Ranches, Chiquita, Constellation Brands, Del Monte Produce, E & J. Gallo, Farming D, Fresh Express, Pereira Farms, Ryan Palm Farms, Tanimura & Antle

California Agriculture

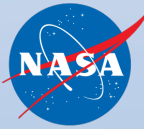
- \$43.5B in cash farm receipts in 2012 from 81,500 farms
- Major domestic/international supplier of specialty crops
- Half of US-grown fruits, nuts, vegetables
- Diversity of crops



Water Resource Management Challenges

- Drought impacts
 - ~20% of full allocation from CVP in 2013 for SJV farmers
 - 0% allocation for 2014
- Competing demands
- Aging water conveyance infrastructure
- Groundwater overdraft
- Water quality and impaired water bodies
 - Nitrate, salinity, selenium





Quantifying Benefits of Using Weather Information in Irrigation Management

Water, Yield and Total Benefits to Farmers from CIMIS				
Crop	Water \$US +	Yield ⁺⁺ \$US	Total \$US	Benefit/Hectare \$US
Trees and Vines Sample				
Almonds	246,000	2,426,500	2,672,500	408
Apples	900	13,900	14,800	366
Avocados	-141,350*	738,000	596,500	760
Grapes	100,850	1,336,500	1,437,3500	730
Pistachios	370,150	6,755,000	7,125,000	630
Plums	556	12,445	13,000	402
Vegetable Sample				
Artichoke	2,500	326,200	328,700	160
Broccoli	2,750	106,100	108,850	730
Cauliflower	5,750	334,100	339,850	870
Celery	3,350	345,750	349,100	1700
Lettuce	26,000	1,361,000	1,387,000	920
Field Crop Sample				
Alfalfa	47,790	325,700	373,500	100
Cotton	345,300	810,500	1,155,800	110

Source: <http://www.cimis.water.ca.gov/cimis/resourceArticleOthersTechRole.jsp>

⁺Money saved due to reduced water bill resulting from using CIMIS.

⁺⁺Increased income from increased yield resulting from using CIMIS.

*Negative number indicates increased water use with CIMIS.

Average reduction in total applied water: 13%

Average increase in yields: 8%

Parker et al., 1996

Opportunity

Standard approach for incorporating information on weather / crop stage into irrigation management practices:

$$ET_c = ET_o * (K_{cb} + K_e)$$

\nearrow
CIMIS

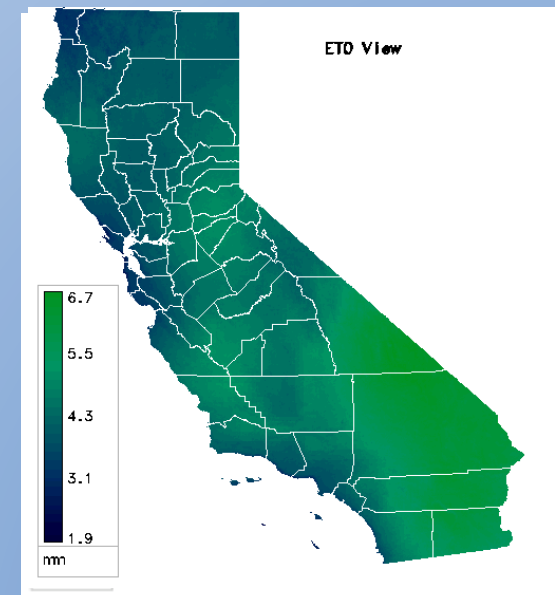
\nwarrow
Satellite



Photo credit: DWR CIMIS

California Irrigation Management Information System (CIMIS)

- Operated by CA DWR since 1982
- >140 stations currently providing daily measurements of ET_o
- **Spatial CIMIS** data now available for CA; 2km statewide grid, daily
- Crop coefficient mapping identified by CA DWR as high priority need for CIMIS



Spatial CIMIS ET_o

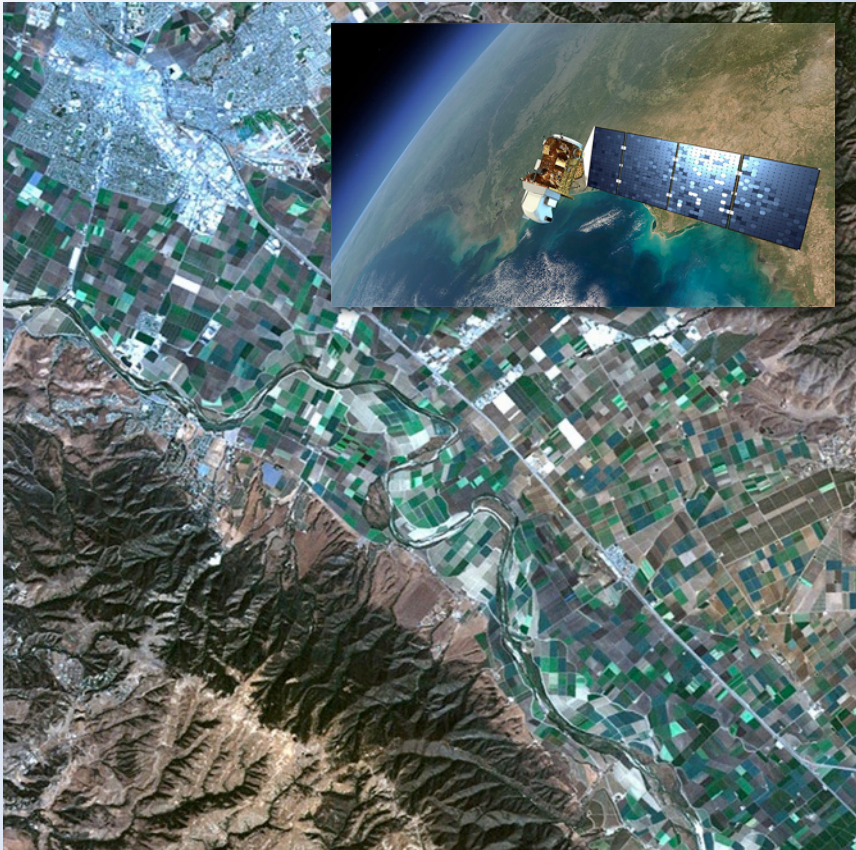
Satellite Irrigation Management Support (SIMS): Objectives



- 1) Develop near real-time estimates of crop water requirements from satellite data to assist growers in optimizing irrigation, and water managers in improving estimates of agricultural water requirements
- 2) Provide web and mobile data interfaces to increase the ability of the agricultural community to access and use satellite data in irrigation management and crop monitoring



Satellite Data

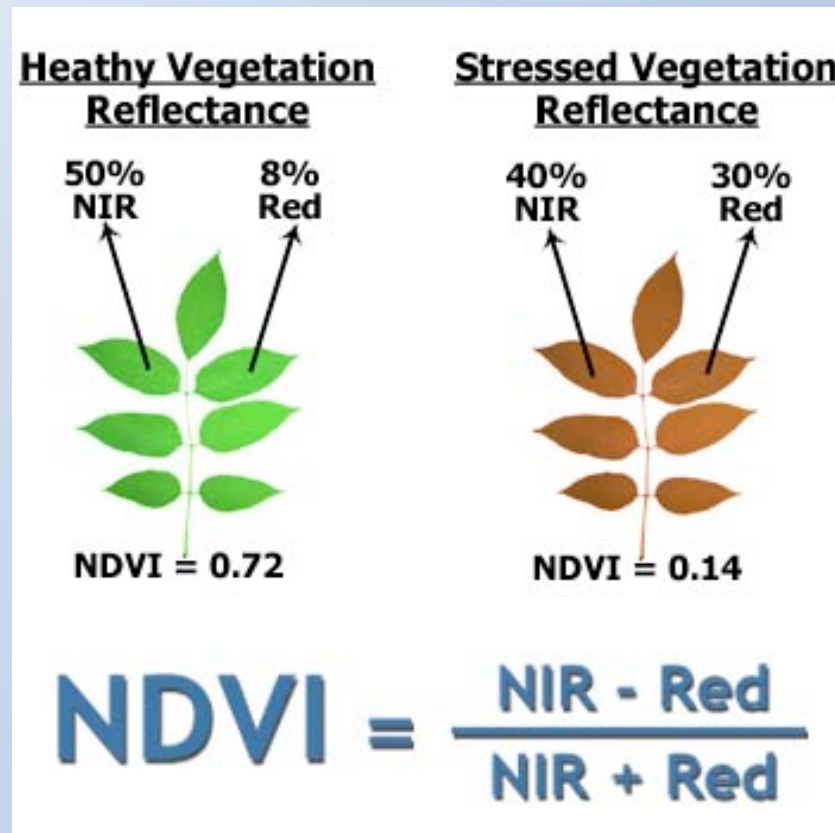


Landsat (TM / ETM+ / OLI)
30m / 0.25 acres
Overpass every 8-16 days



Terra / Aqua (MODIS)
250m / 15.5 acre
Daily overpass

Normalized Difference Vegetation Index



Credit: ODIS

Commonly used remote sensing index of vegetation condition



TOPS Satellite Irrigation Management Support

Username:

Password:

Login

Go to:

Search

[About](#) [Help](#)

Select Date: 2011-07-07



Normalized Difference
Vegetation Index
(NDVI); 8-day
composite from Landsat
and MODIS

0.0 0.2 0.5 0.8 1.0
NDVI

SIMS Data Layers

- ☐ ETcb
2011-07-07
- ☐ Crop coefficient (Kcb)
2011-07-04 to 2011-07-11
- ☒ Veg. Index (NDVI) gapfilled
2011-07-04 to 2011-07-11
- ☐ Veg. Index (NDVI)
2011-07-04 to 2011-07-11

Base Layer

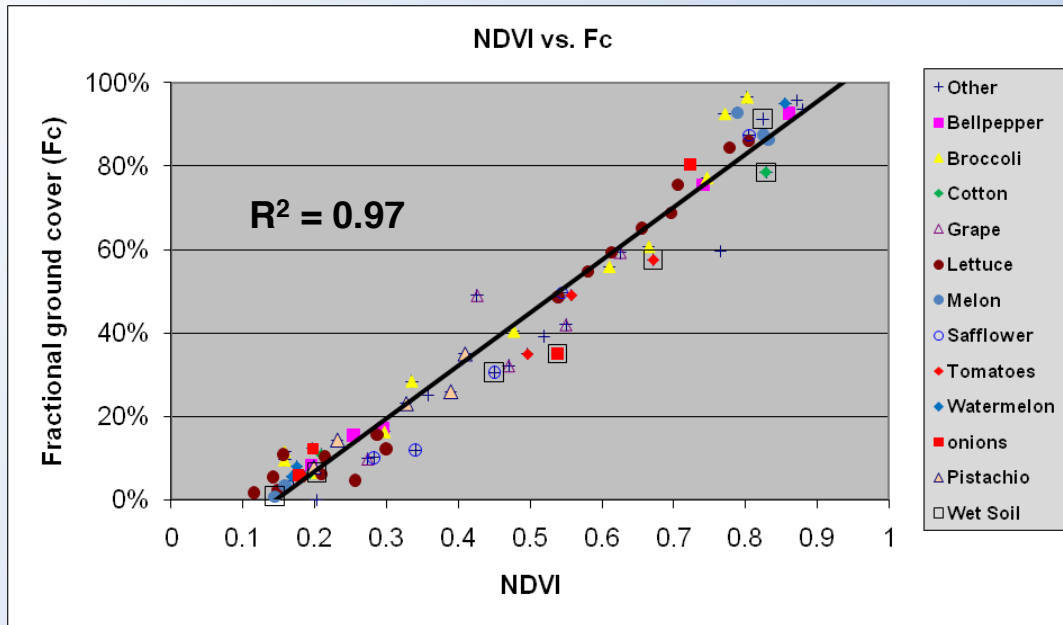
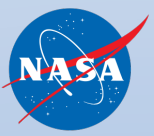
- ☒ Google Satellite

35.39402 N, -119.85320 W

Disclaimer: This data is for research and evaluation purposes only.

NASA Official: [Ramakrishna R.Nemani](#)Curator: [Forrest Melton](#)[Privacy Statement](#)

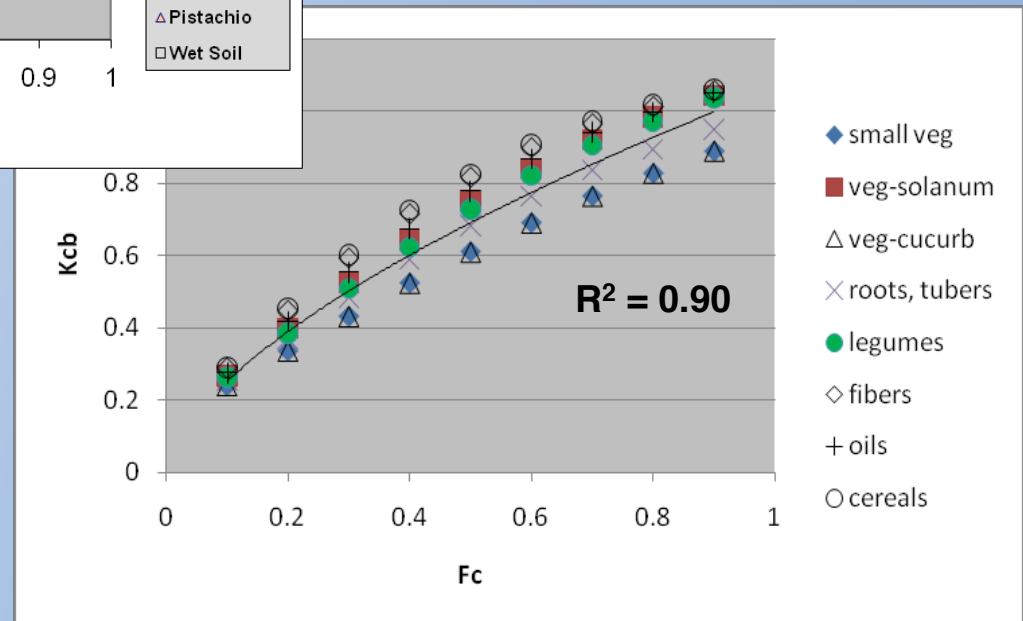
Approach: Mapping Crop Coefficients and Indicators of Crop Water Requirements from Satellite Data



USDA studies provide basis for linking satellite vegetation indices (NDVI) to fractional cover.

Trout et al., 2008; Johnson & Trout, 2011

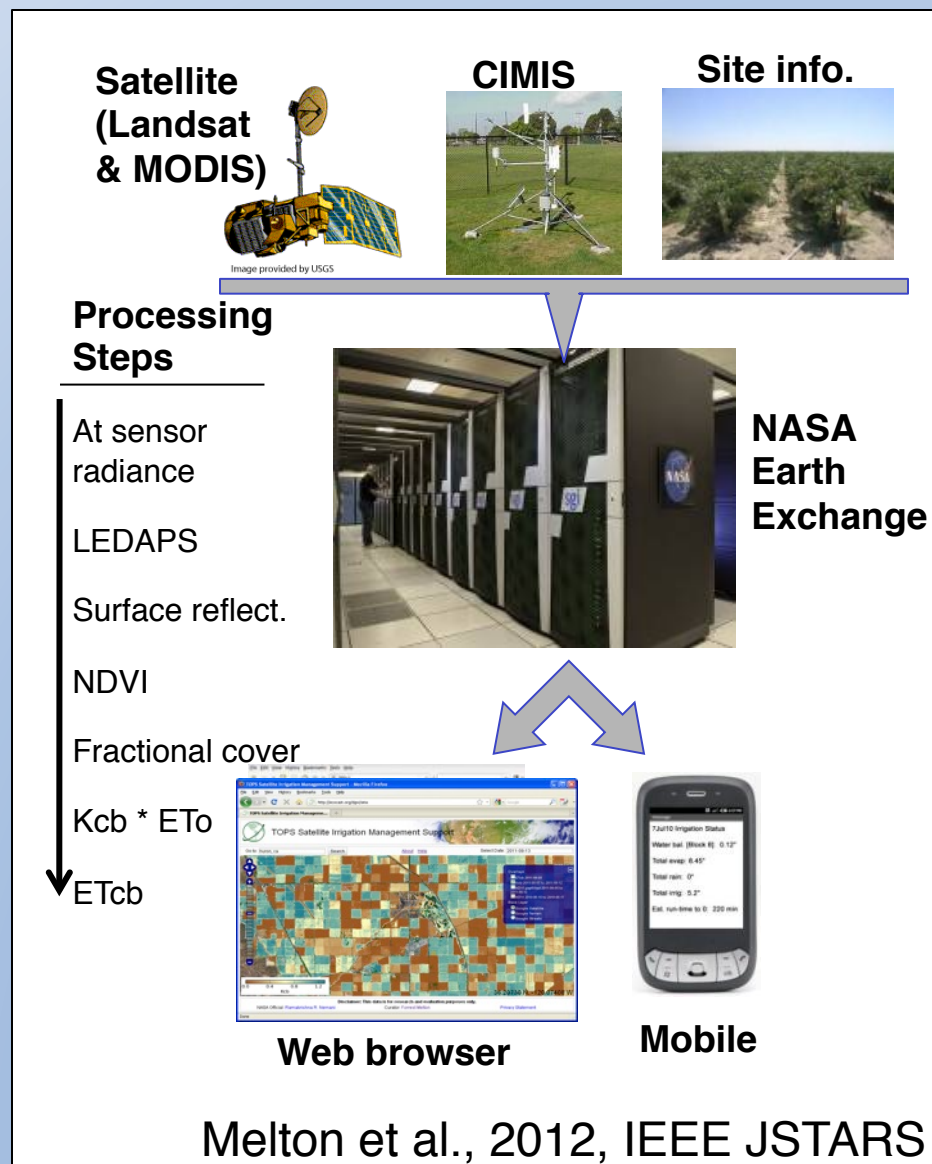
Recent studies by Allen & Pereira (2009) and others provide basis for linking fractional cover to K_{cb} for a range of crops.

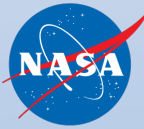


Also see Bryla et al., 2010; Grattan et al., 1998; Hanson & May, 2006; Lopez-Urrea et al., 2009

Satellite Irrigation Management Support (SIMS) Framework

1. Integration of satellite and surface measurements
2. Prototyping accelerated by NASA high end computing resources
3. Integration with irrigation management tools (CropManage, VSIM)
4. Freely available data
5. Outreach and education through partnerships with Western Growers and agricultural extension services





Satellite Irrigation Management Support (SIMS) Framework



TOPS Satellite Irrigation Management Support

Username:

Password:

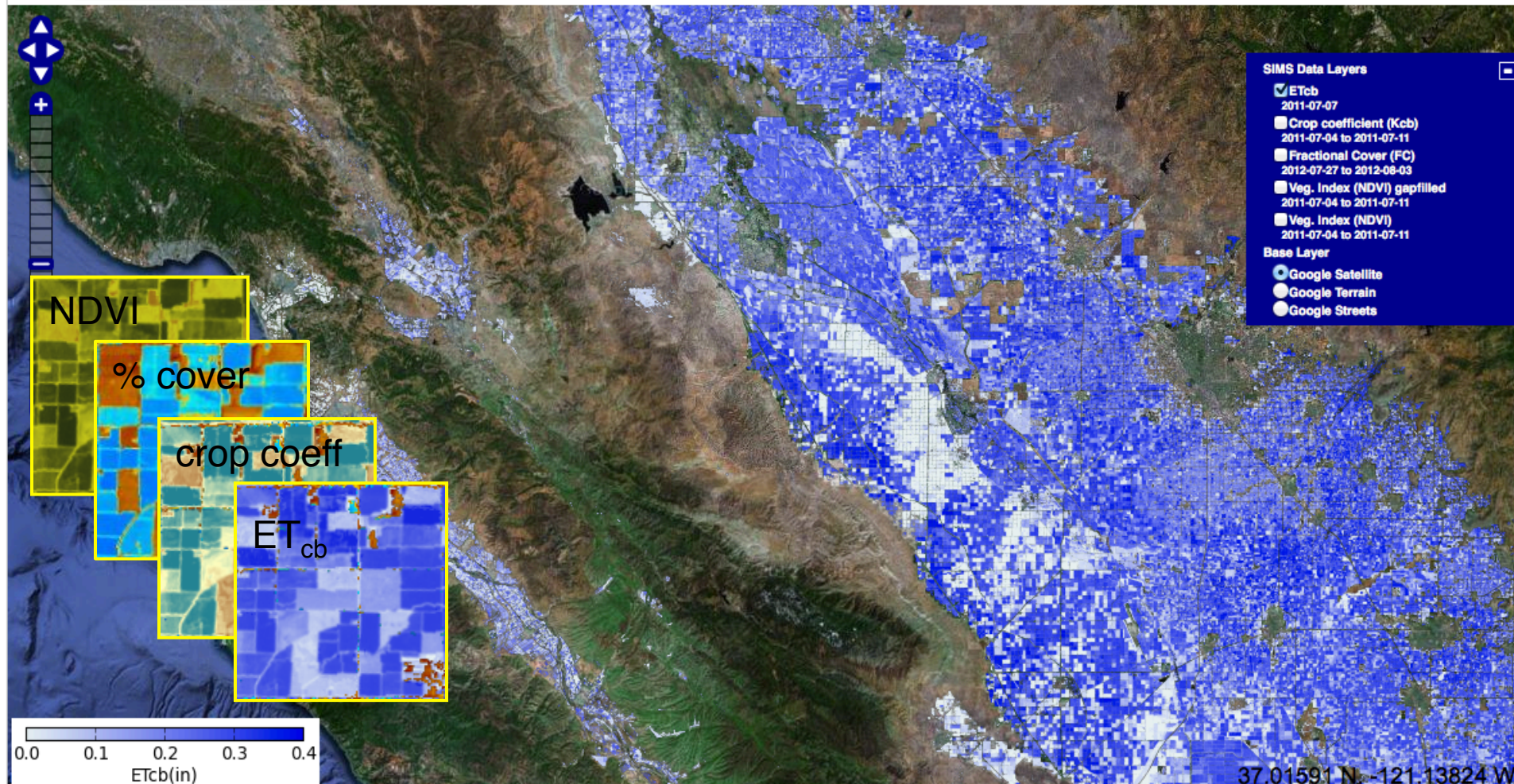
Login

Go to:

Search

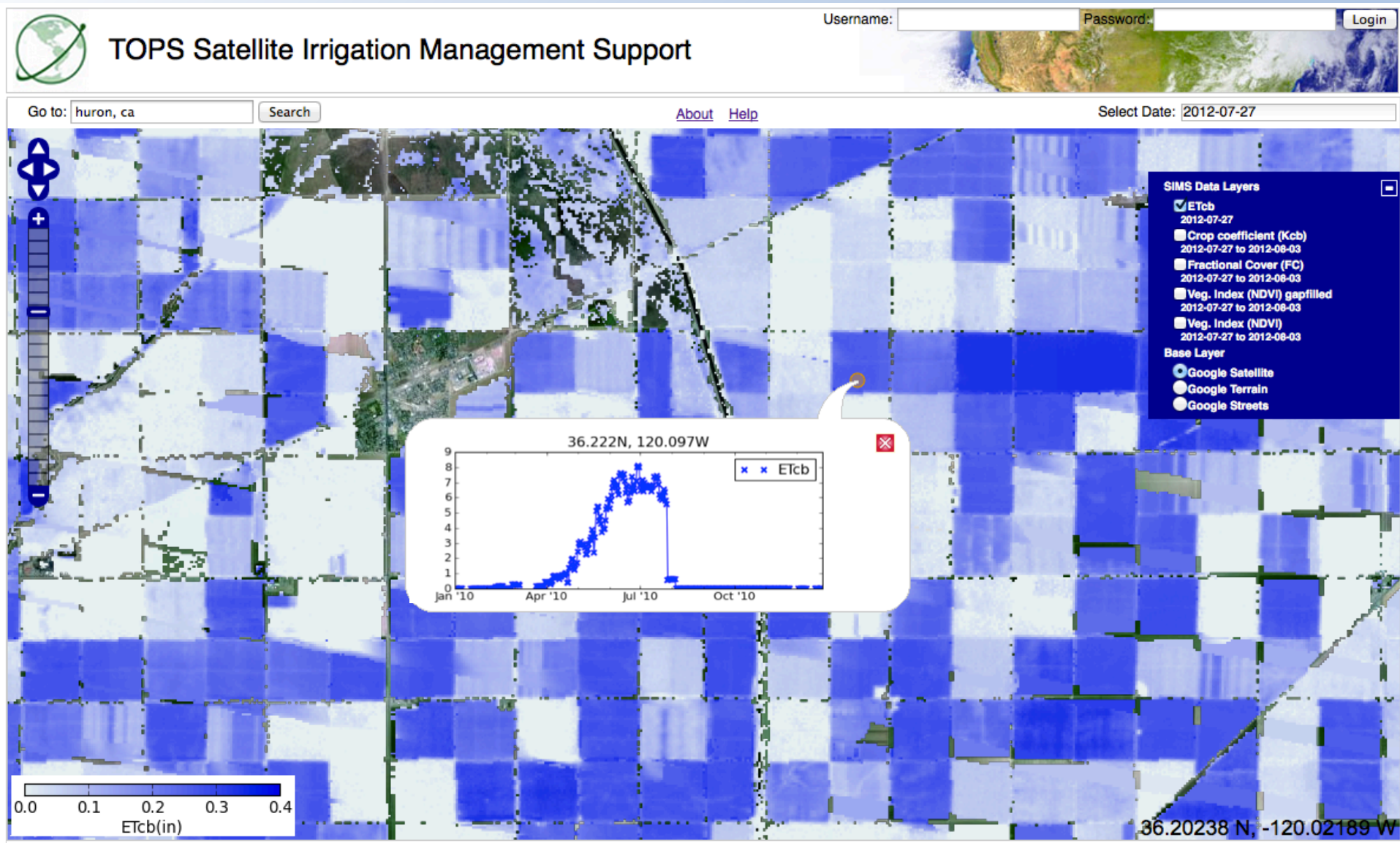
[About](#) [Help](#)

Select Date: 2011-07-07

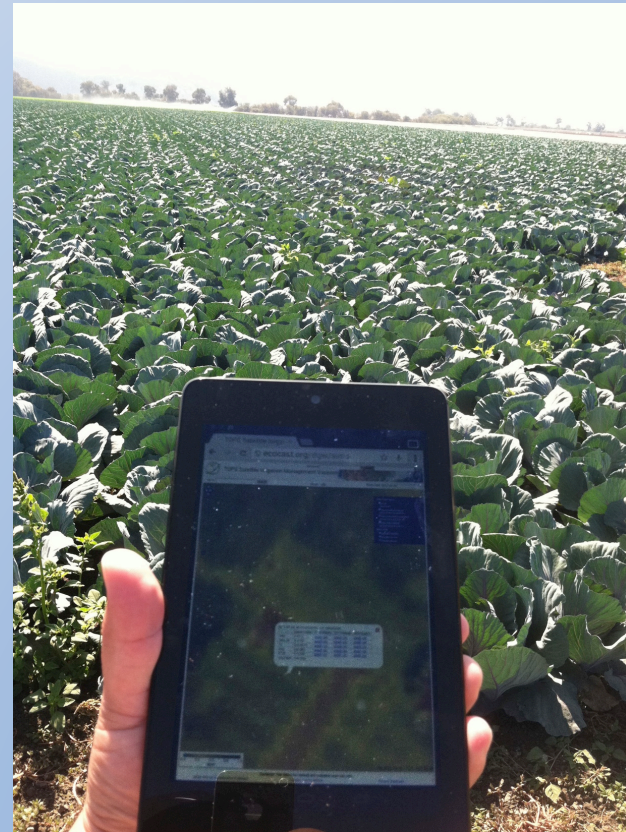
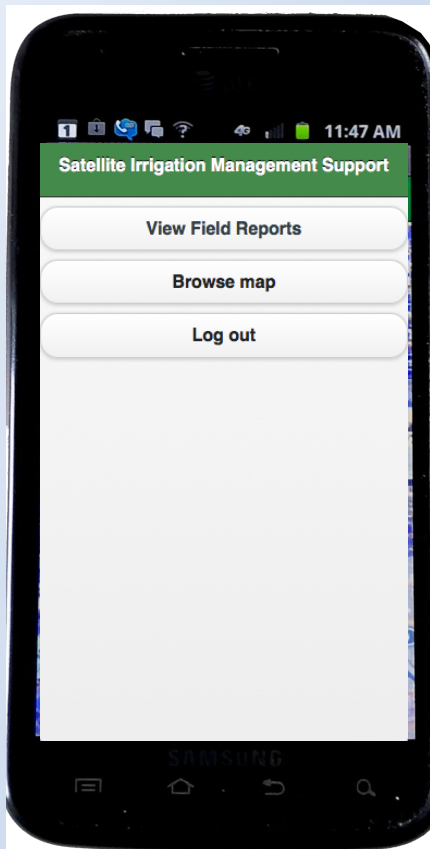




Satellite Irrigation Management Support (SIMS) Framework



Delivering Data to the Field: Mobile Interfaces



Mobile-based interfaces important for enhancing access to data

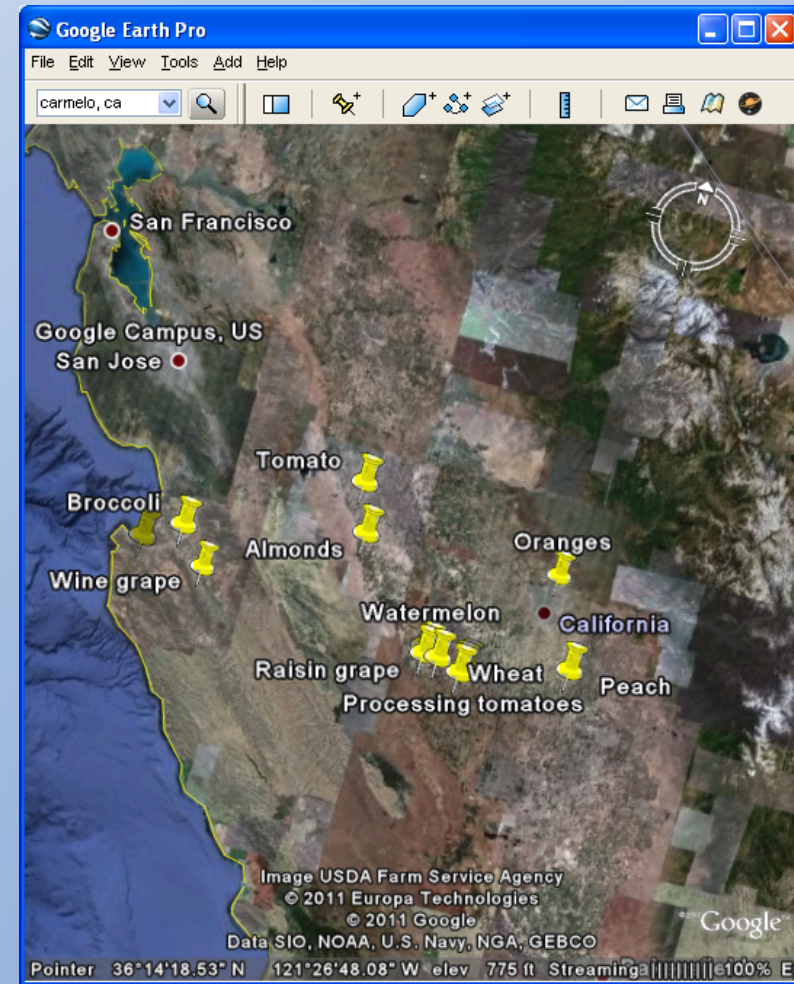
Verification and Validation: Sensor Networks



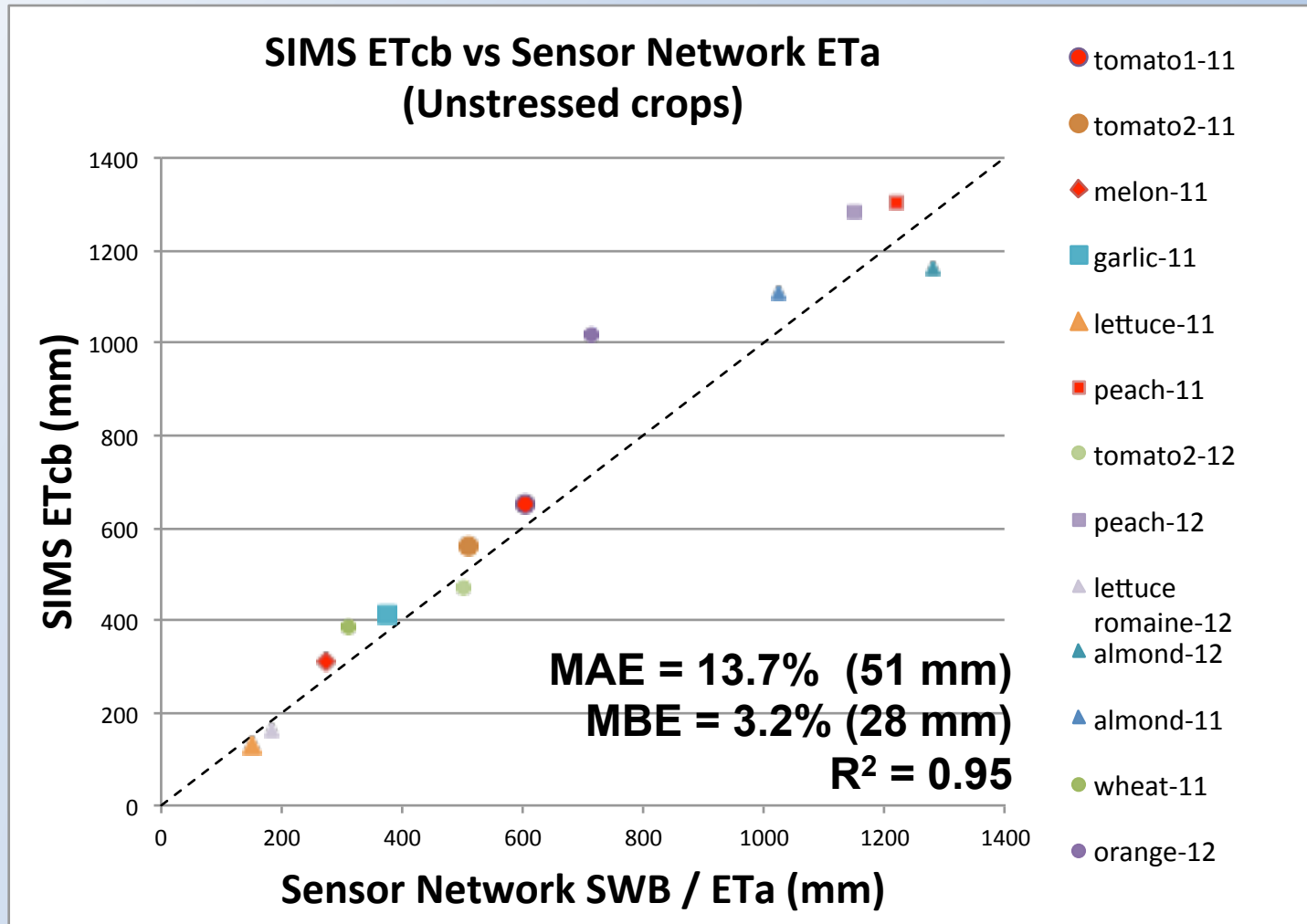
Sensor Network Installations

Crop Type	Crop	Location
Grain	Corn*	CSU Fresno
Grain	Wheat	San Joaquin Valley
Row	Garlic	San Joaquin Valley
Row	Lettuce*	SJ & Salinas Valley
Row	Broccoli*	Salinas Valley
Row	Cauliflower	San Joaquin Valley
Row	Tomato(2)*	San Joaquin Valley
Row	Cotton (drip)*	San Joaquin Valley
Vine	Melon	San Joaquin Valley
Vine	Wine grapes*	Salinas Valley
Vine	Raisins*	San Joaquin Valley
Tree	Peach*	San Joaquin Valley
Tree	Almond*	San Joaquin Valley
Tree	Orange*	San Joaquin Valley

*Surface renewal instrumentation.

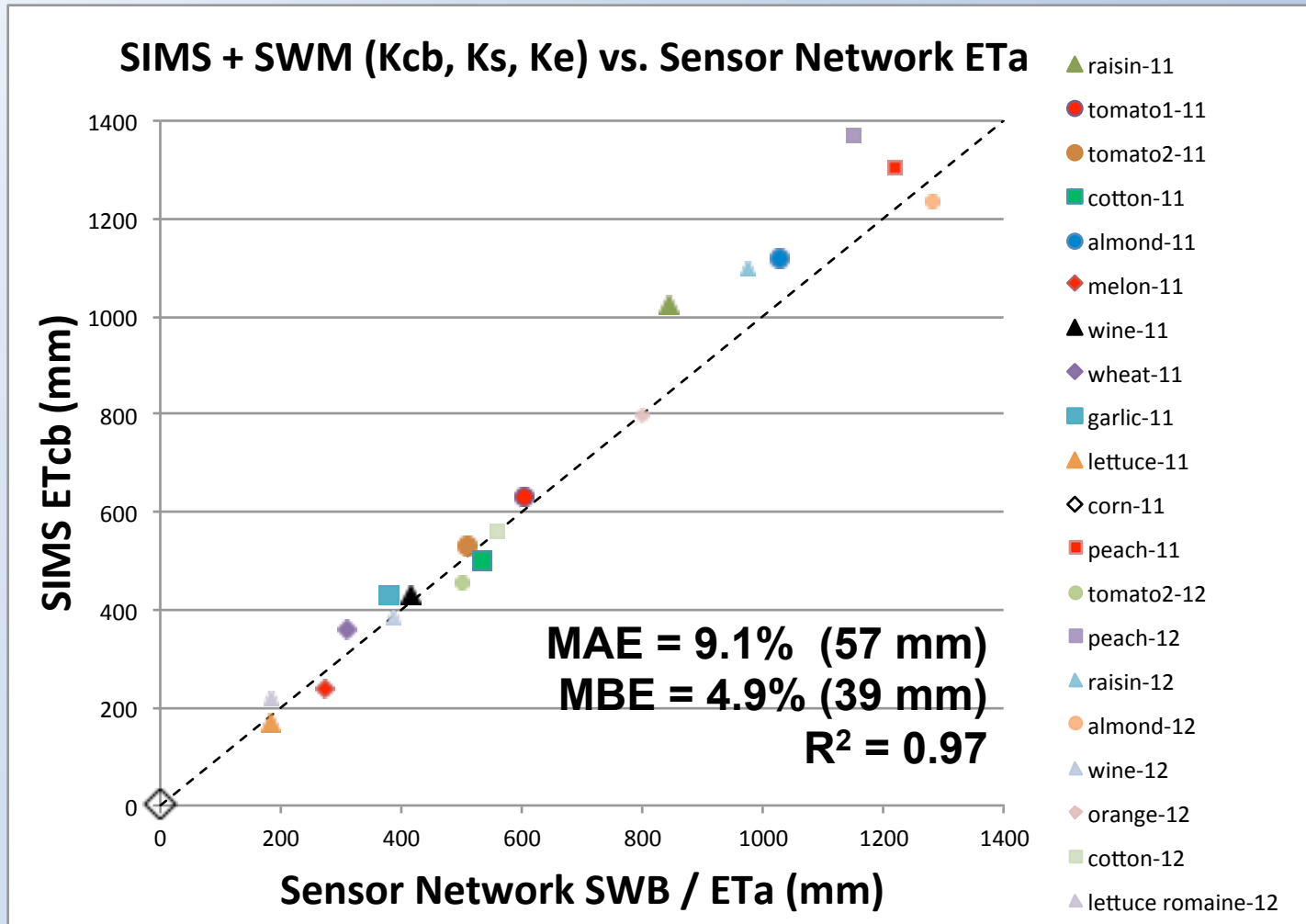


Verification and Validation: Results



Comparison of seasonal ET totals from SIMS and the sensor network for sites instrumented in 2011 and 2012, excluding intentionally stressed crops (wine grapes, raisins, and cotton).

Verification and Validation: Results

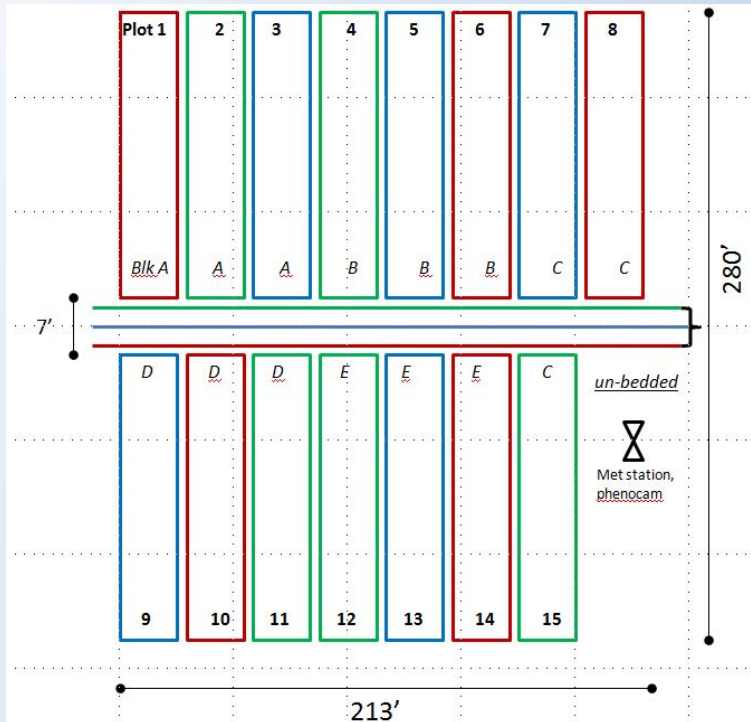


Comparison of seasonal ET totals from SIMS and the sensor network for sites instrumented in 2011 and 2012. Ke and Ks coefficient via a soil water balance model based on FAO-56 (Allen et al., 1998).

Yield Trials

Lettuce & Broccoli

USDA ARS, Spence Road, Salinas



Treatments:

- Standard practice
- SIMS
- CropManage

- 3 tmts, 5 reps, block randomized design
- Total area: ~1.4ac (0.57 ha)
- Two years of data: 2012 & 2013

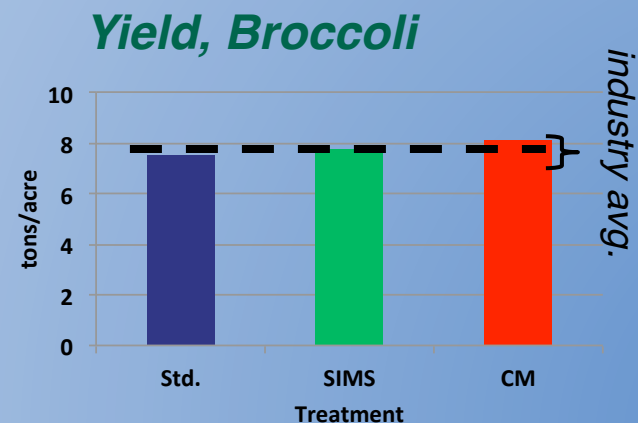
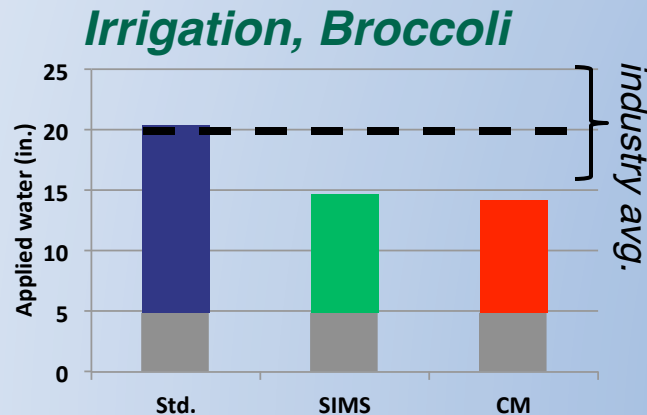
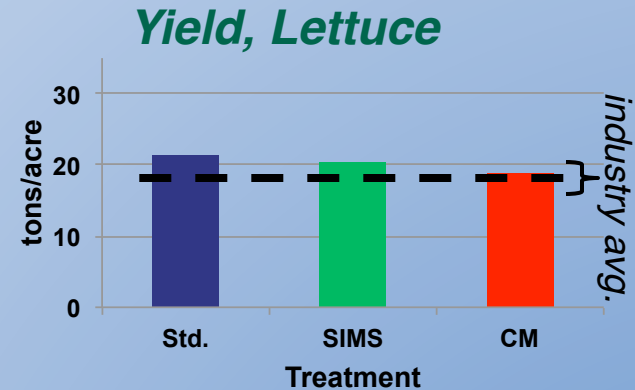
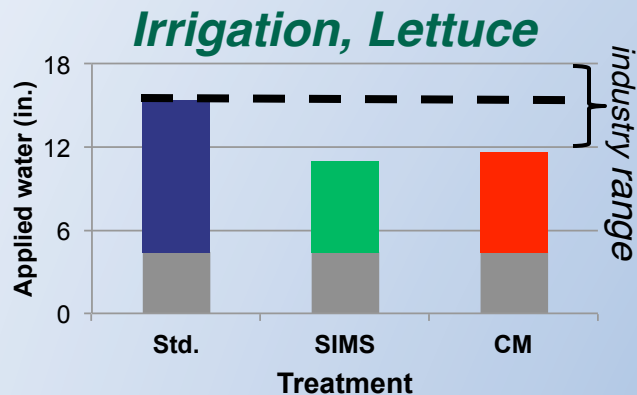
PI: Lee Johnson; Co-I: Michael Cahn
 Collaboration with UCCE, USDA ARS,
 Fresh Express, Tanimura & Antle



Yield Trials: Results to Date

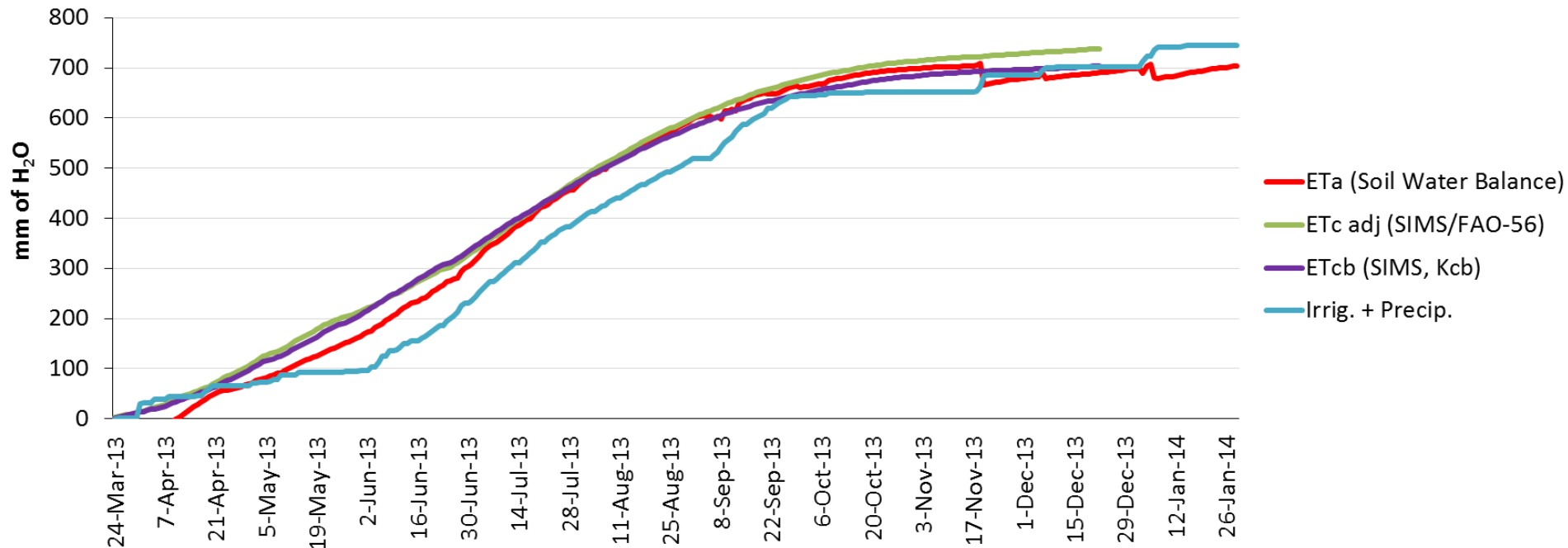
- Results to date confirm savings in applied water of 22-33% without reductions in yield or quality

■ Standard practice
■ SIMS
■ CropManage



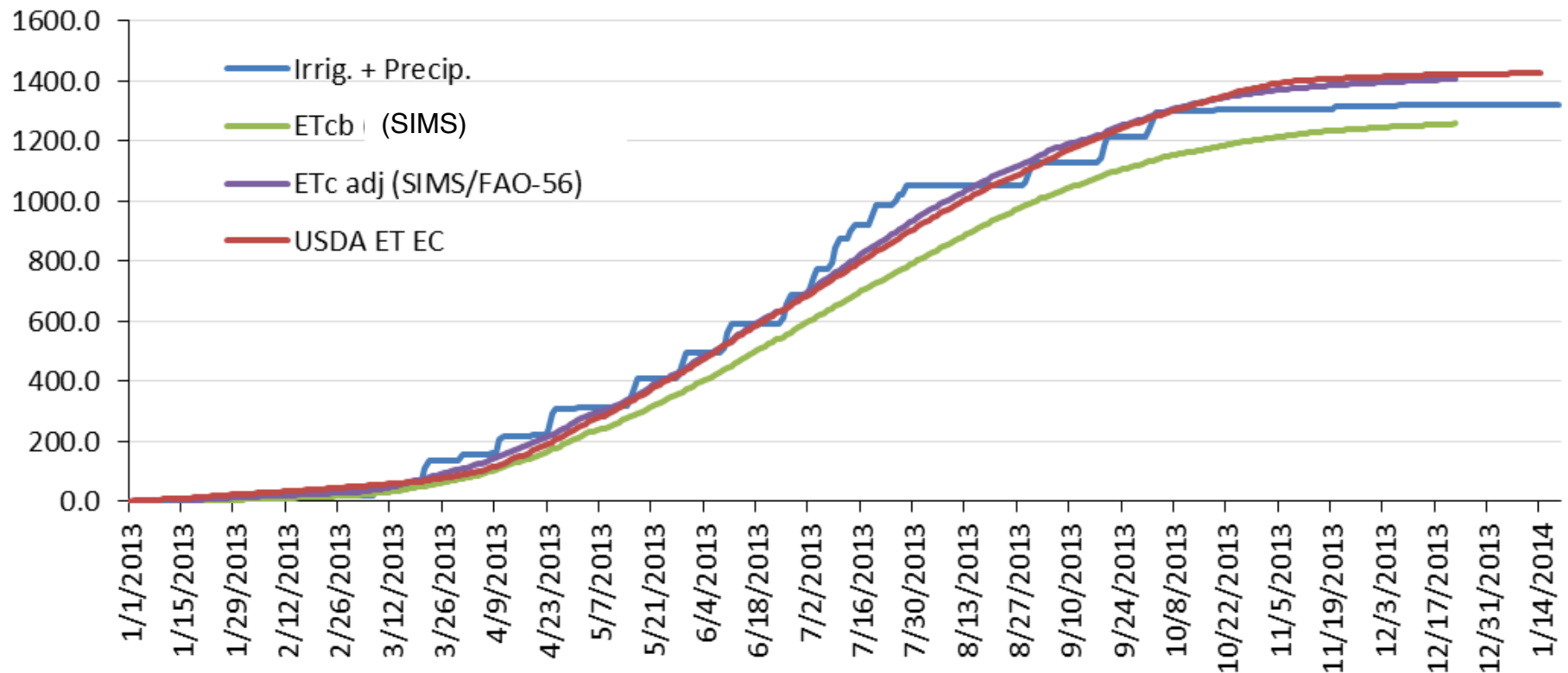
Examples of Efficient On-Farm Water Use

Irrigation vs Evapotranspiration, 2013 Pinot Noir, Galt, CA



Examples of Efficient On-Farm Water Use

Irrigation vs Evapotranspiration, 2013 Peaches, Kingsburg, CA



Thank you



forrest.s.melton@nasa.gov